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ALGORITHM PERFORMANCE EVALUATION

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Traditionally, the performance of adaptive antenna systems is measured using automated antenna array pattern measuring equipment. This measurement equipment produces a plot of the receive gain of the antenna array as a function of angle. However, communications system users more readily accept and understand Bit Error Rate (BER) as a performance measure. The work reported on here was conducted to characterize adaptive antenna receiver performance in terms of overall communications system performance using BER as a performance measure.

The adaptive antenna system selected for this work featured a linear array, Least Mean Square (LMS) adaptive algorithm and a high speed Phase Shift Keyed (PSK) communications modem.

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LIST OF FIGURES

1.0 Introduction

This report contains the results of work accomplished under task one of the in house project 45194263, entitled "Communications Adaptive Array Processor Evaluation".

Traditionally, the performance of adaptive antenna systems is measured using automated antenna array pattern measuring equipment. This measurement equipment produces a plot of the receive gain of the antenna array as a function of angle. In an anechoic chamber, a linear array is illuminated by a desired signal and a number of interference sources. The desired signal is broad side to and in the main beam of the array. The interference sources can be placed in the peak of a side lobe where they are most affective. The phase and amplitude weights required to null the interference sources are calculated via an adaptive algorithm. The antenna pattern is then plotted using a Continuous Wave (CW) tone. Rotating the array gives the desired plot. If the plots are computed with the sources in the far field (>2D/λ between antenna array and sources) they are an accurate picture of the interference suppression performance of the adaptive array. However, communications system users more readily accept and understand BER as a performance measure. The work reported on here was conducted so that adaptive antenna receivers performance could be characterized in terms of overall communications system performance using BER.

ADAPTIVE ARRAY PROCESSING TESTBED

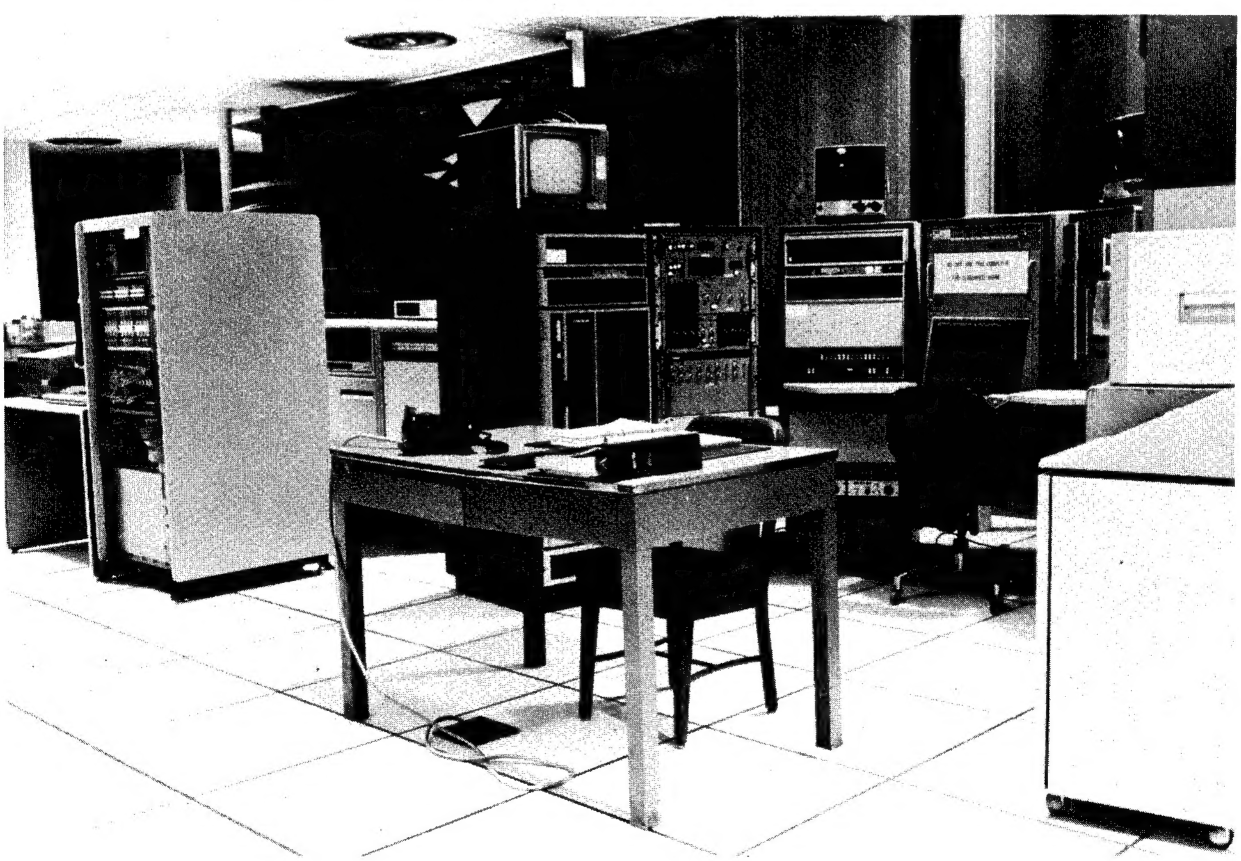

Figure 1

2.0 Adaptive Spatial/Temporal Processor Testbed

RL/C3 has a unique adaptive array processing testbed. The testbed shown in Figure 1 consists of a rectangular anechoic chamber, a **F**lexible **A**daptive **S**patial **S**ignal **P**rocessor (**FASSP**), and antenna pattern recorder, various types of jammer/desired signal sources and satellite communications simulation and analysis programs.

The testbed simulation/analysis computer programs are used to study and compare adaptive processing system concepts, techniques and algorithms. This provides a "fast-look" approach to determine the merit and feasibility of a concept. If the results show promise, the concept is tested further using real signals and adaptive processor hardware to determine the actual benefit attainable. The testbed is reconfigurable and functions as a tool to support the development of methodologies for comparing and evaluating new adaptive spatial processing algorithms, architectures, techniques and devices suitable for meeting satellite communications requirements (such as those for the **D**efense **S**atellite **C**ommunications **S**ystem (**DSCS**)).

2.1 Anechoic Chamber

The anechoic test chamber shown in Figure 2 is a rectangular structure 40 foot long, 28 foot wide and 18 foot high [5]. The inner chamber is isolated from RF fields, over the range 150 MHz to 18 GHz, by at least 100 dB. It has a six foot diameter spherical quiet zone midway between the ceiling and the floor and about 50 inches from the tips of the absorber on the back wall.

ANECHOIC CHAMBER

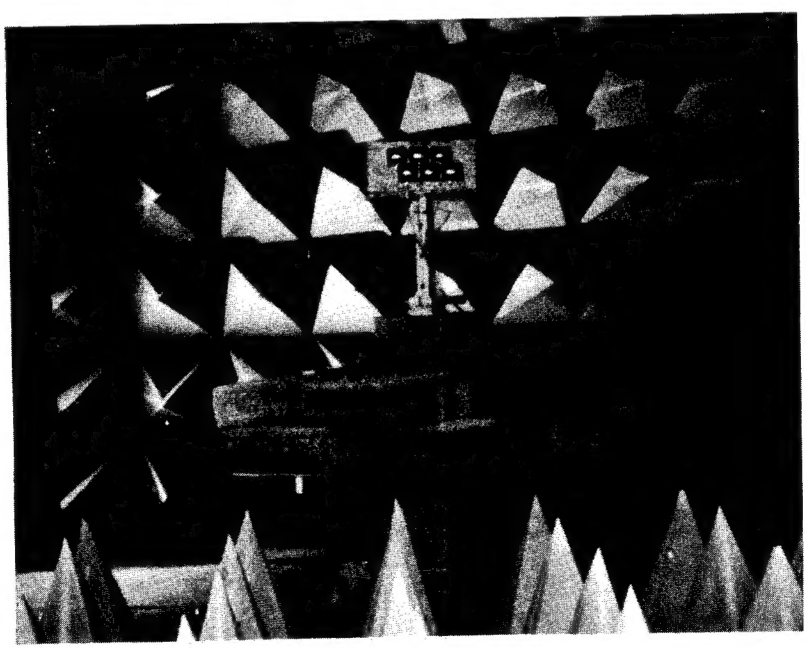

Figure 2

The receive element array is positioned in the center of the quiet zone to minimize reception of all reflected signals. All chamber walls, ceilings and floors, except walkways, are covered completely with energy (RF) absorbing material. A Scientific Atlanta model 5315C-5 antenna positioner is installed in the chamber. The tip of the model tower (which supports the array elements) is located in the center of the "quiet zone". The chamber is wide enough and has provisions so that several signal sources can be used simultaneously at the back wall opposite to the "quiet zone".

Six feet of the 40 foot chamber is partitioned off and is used as an equipment room to house the signal sources and antenna positioner controls. Absorber panels are removable to allow access for mounting signal/jammer antennas. Signal and control connections between the chamber and the laboratory equipment (FASSP and Scientific Atlanta 2020 system) are provided through bulkhead feed through panels at each end of the chamber.

All functions such as source power, frequency, mode and receiver antenna position (pedestal rotation) are controlled from outside the chamber.

2.2 Flexible Adaptive Spatial Signal Processor (FASSP)

The FASSP [4] testbed is shown in Figure 3. All adaptive spatial processing systems consist of an array of receiving elements, which provide the spatial diversity required to cancel interference signals, an adaptive processor that processes the signal samples received by the array elements to compute the adaptive weights that produce the desired spatial response and a weighting network to apply the adaptive weights to the signals received by the elements of each input channels.

The design of adaptive spatial processing systems is very complicated because of the close interaction between these three basic components. Although computer simulations can be used to compare the performance of adaptive algorithms and techniques, the hardware implementation effects cannot always be easily modeled.

With this in mind, RL/C3BA conceived the ideas of a **F**lexible **A**daptive **S**patial **S**ignal **P**rocessor **(FASSP)**, which was designed and fabricated for RL by Syracuse Research Corp. The FASSP is a general purpose flexible hardware adaptive array processor system that supports the integration/test of adaptive processing algorithms, architectures, techniques and real components.

The FASSP system was fabricated with high performance quality components and consists of 12 real RF receivers and weighting networks that are reconfigurable. The designer uses a computer-based operating system to select the adaptive algorithms and hardware configuration and specify the necessary adaptive processor system parameters. The adaptive processor system performance can then be evaluated using real RF desired and jamming signals.

FLEXIBLE ADAPTIVE SPATIAL SIGNAL PROCESSOR (FASSP)

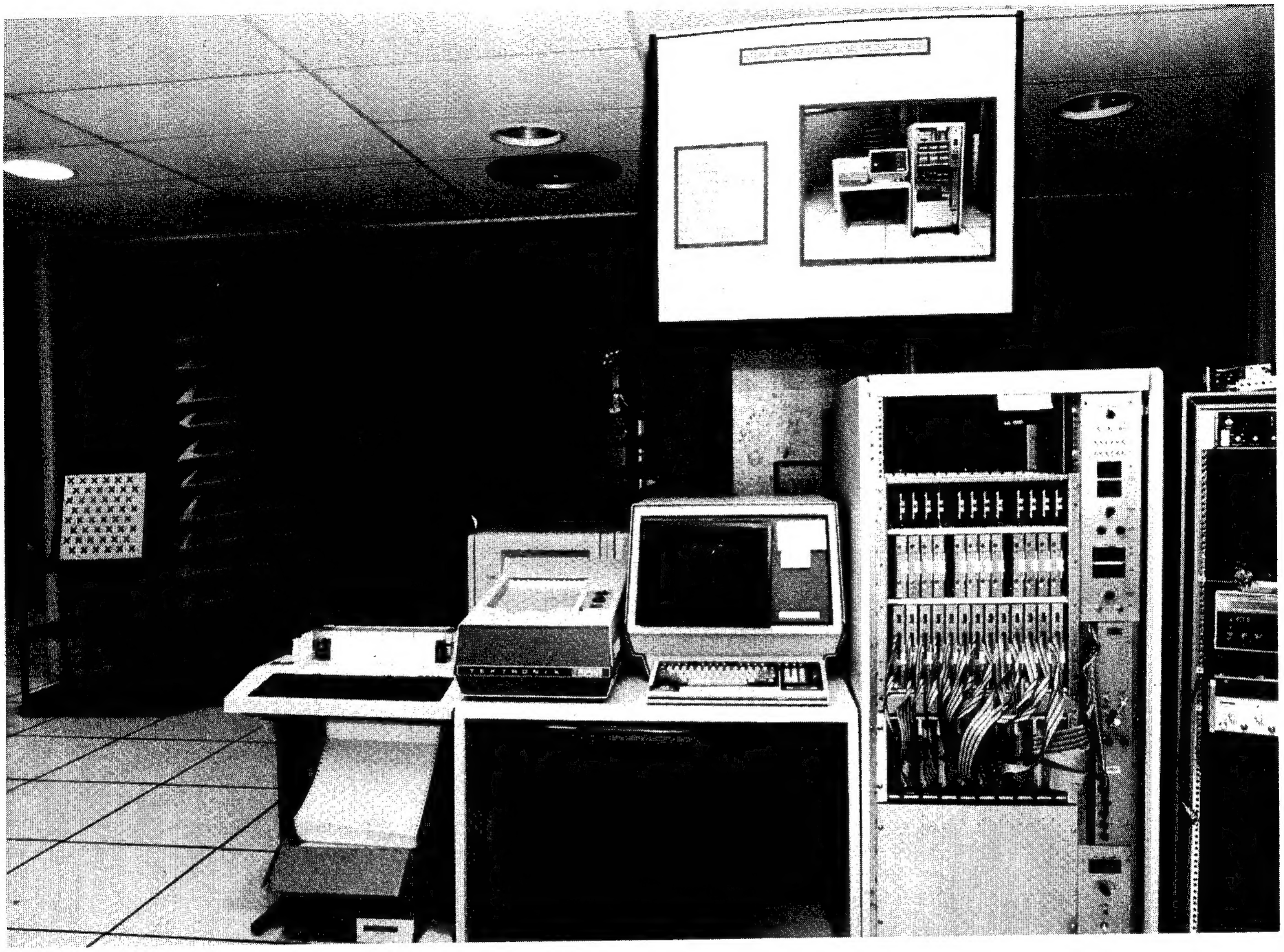

Figure 3

3.0 Conventional Adaptive Array Baseline

The conventional adaptive array processing system shown in Figure 4 was used as a baseline system configuration. The receiver antenna was a linear array of four standard gain horns separated by 2/3 wavelength spacing. The array was located on the positioner with the elements centered in the chamber quiet zone.

CONVENTIONAL ADAPTIVE ARRAY

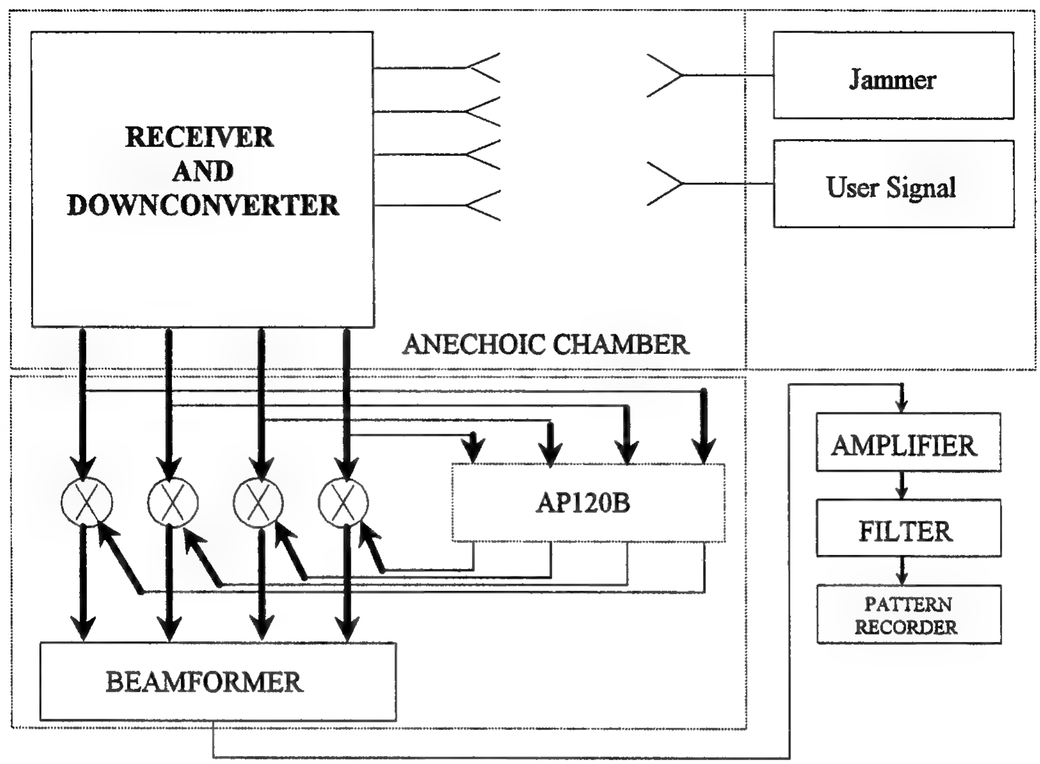

Figure 4

The **C**ontinuous **W**ave (**CW**) and wide band noise jammer antennas were located at the opposite end of the chamber. One jammer transmitter element was positioned broadside/boresight (zero degrees azimuth, zero degrees elevation) to the array. Using a CW signal the antenna array response can be plotted.

The array response plot indicated that the main beam is centered at zero degrees azimuth and the sidelobes are located at plus or minus fourteen degrees azimuth. The second jammer transmit element was positioned at fourteen degrees centered on one of the side lobes.

Nulling and beamforming functions were then performed using desired and jamming RF signals at each position.

4.0 BER Performance Measure

The **B**it **E**rror **R**ate (**BER**) performance as used here is defined to be a plot of BER as a function of **S**ignal to **J**ammer (**S/J**) ratio. The advantage of the BER performance measure is its ability to measure the performance of an adaptive antenna receiver in terms of link quality. For a given adaptive array receiver configuration, the BER performance measure will concisely define link quality in terms of S/J.

5.0 Test Results

The hardware setup for the tests is shown in Figure 5. The figure indicates the interconnection between Modem, BER counter, FASSP and other ancillary equipment required for synchronize and filtering. Also indicated are the power levels, frequencies and equipment model numbers.

TEST SETUP

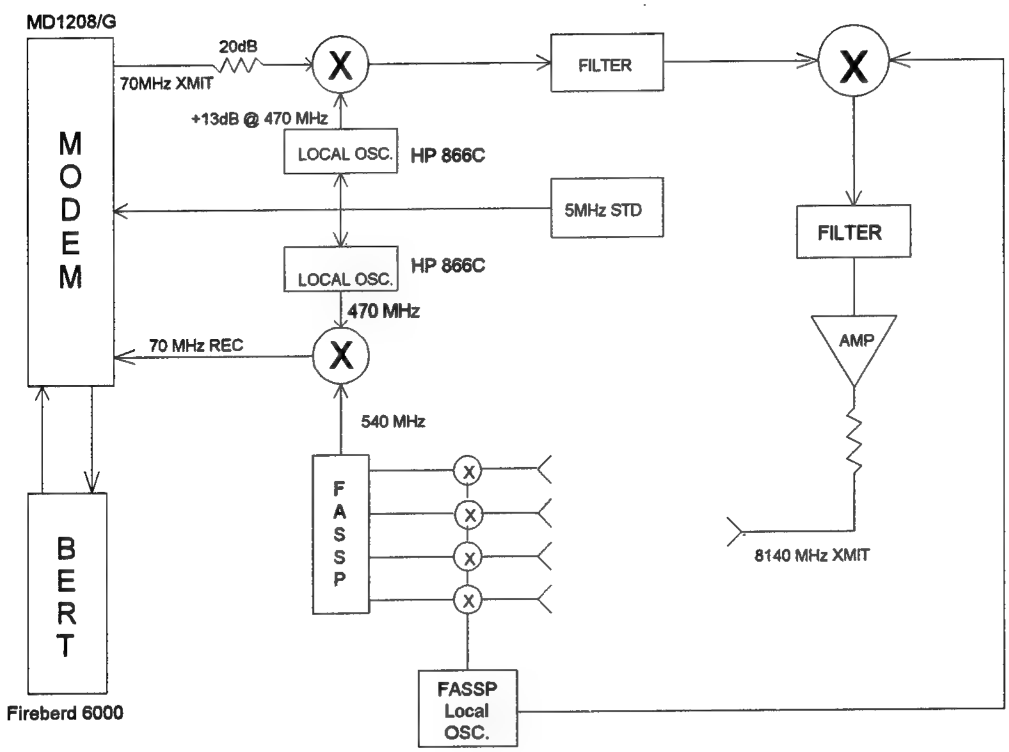

Figure 5

Figures # 6 and 7 indicate the BER performance of the **L**east **M**ean **S**quare **(LMS)** adaptive antenna system. The LMS algorithm was chosen for its simplicity and robust behavior. Both figures are a plot of BER as a function of signal to interference power. For both figures, Series 1 is the adapted performance and Series 2 is the unadapted performance. Figure # 6 is the unconstrained case. For the unconstrained case, the LMS algorithm is not constrained to maintain gain in the direction of the desired signal. Figure # 7 is the constrained case. For the constrained case, the LMS algorithm is constrained to maintain gain in the direction of the desired signal. It is clear from the plots that the adaptive array interference canceller is quite effective for signal to interference ratios less than -15dB.

LMS PERFORMANCE UNCONSTRAINED

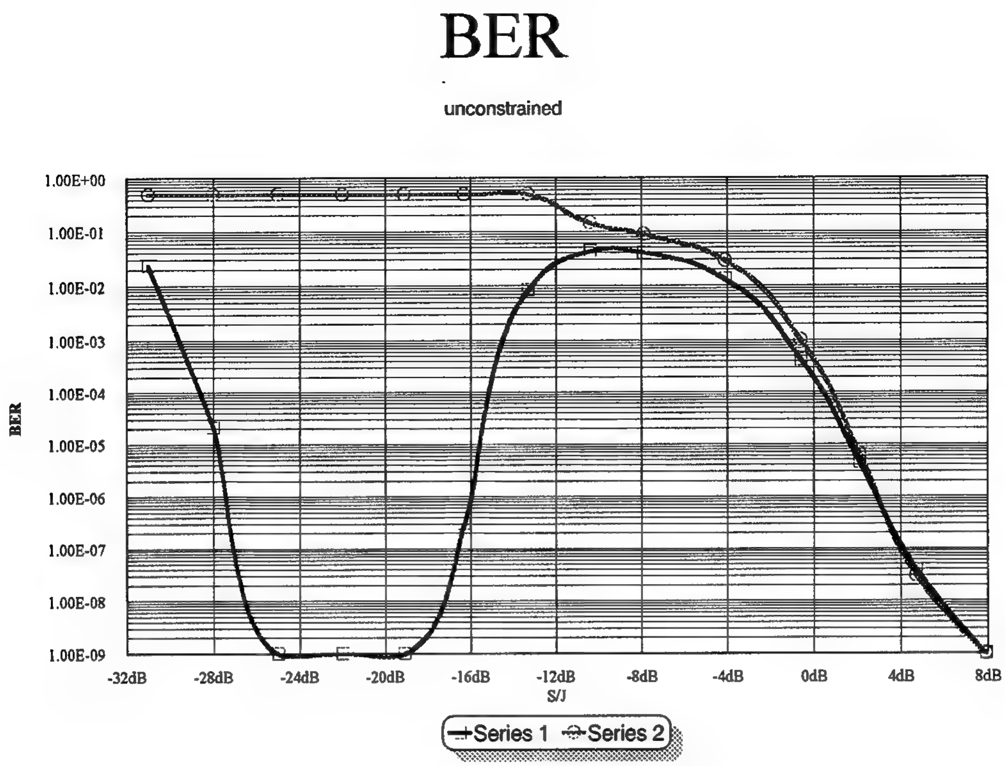

Figure 6

LMS PERFORMANCE CONSTRAINED

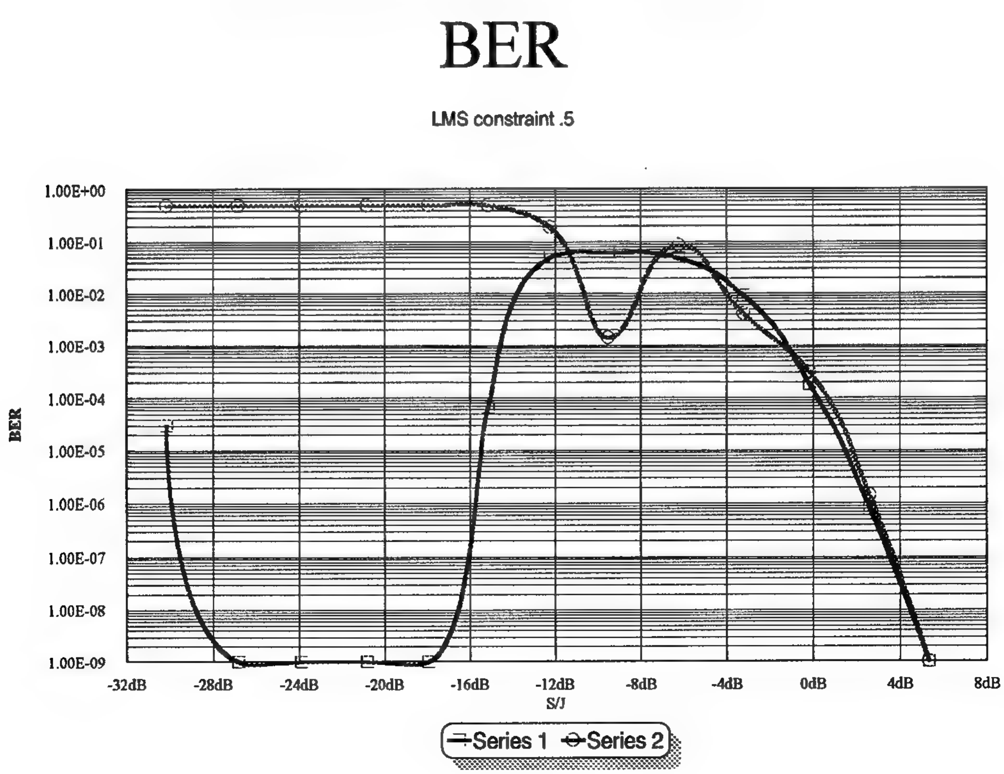

Figure 7

6.0 Conclusions and Recommendations

The BER performance measure provides a good overall assessment of the complete communications system as well as the adaptive antenna subsystem performance. In both Figures # 6 and 7, Series 2 indicates the normal PSK modem performance. As the signal to noise ratio degrades, the BER also degrades. The measure also clearly identifies performance characteristics of the adaptive algorithm under investigation. As indicated by Figures # 6 and 7 Series 1, the LMS adaptive algorithm is not very effective for signal to interference ratios greater than -15dB. This is typical behavior for power inversion algorithms. The plots also show that from -15dB to -28dB the adaptive antenna subsystem provides excellent performance enhancement. The measure also indicates FASSP hardware dynamic range limitations characterized by poor performance for signal to interference ratios less -28dB.

As a result of this effort, it has been shown that the BER performance measure is quite effective as a tool for evaluating communications systems that employ adaptive antenna interference cancellers. This work does not address the use of the BER measure as a tool to compare adaptive antenna algorithms. Follow on work should address this issue.

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